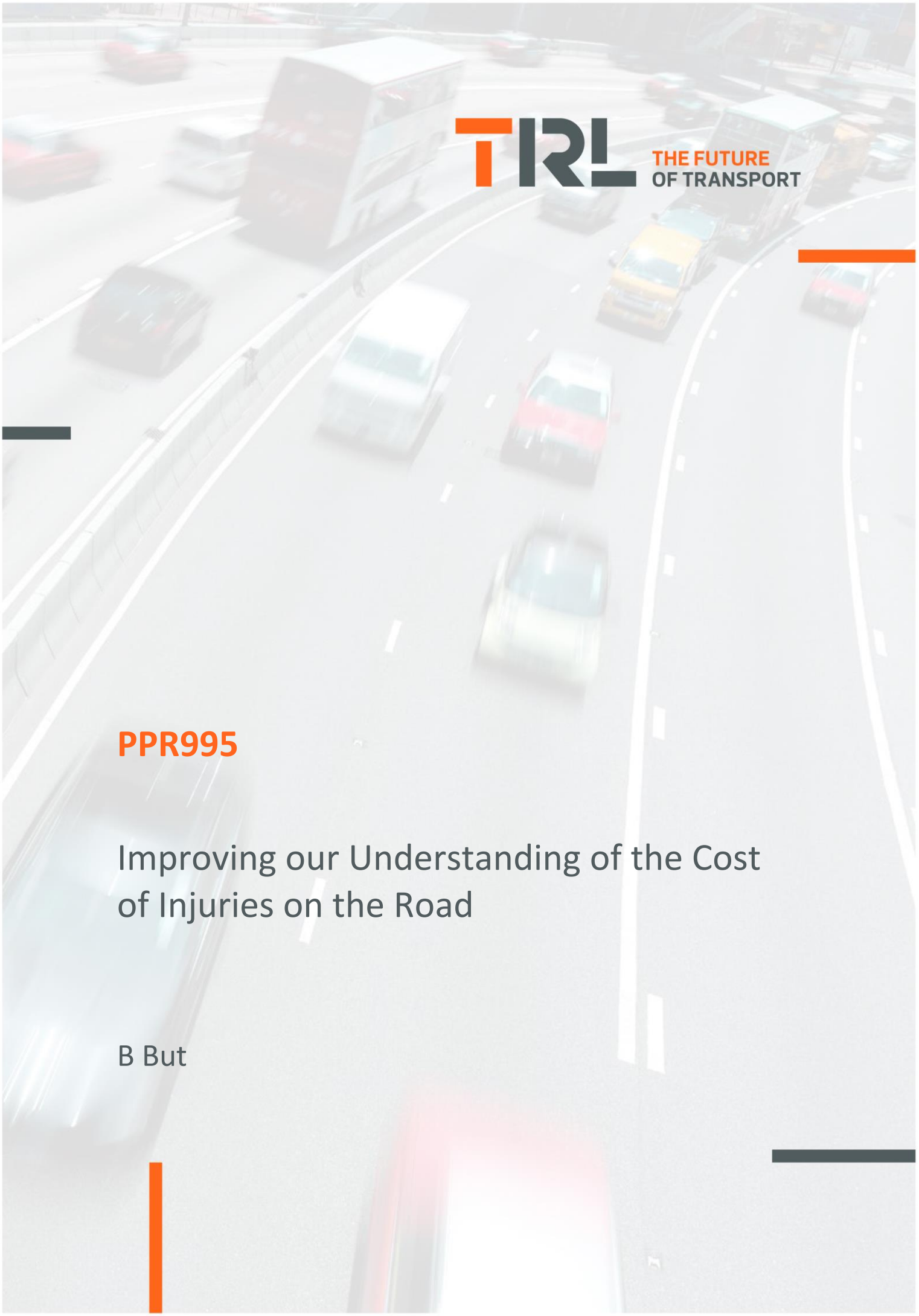

PPR995

Improving our Understanding of the Cost of Injuries on the Road

B But

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Executive summary

Road collisions cause immense human suffering and economic loss. The robust assessment of relevant costs is important in supporting Cost Benefit Analysis (CBA) of safety measures. In the UK, the methodology for evaluating these costs has been in use since 1990s. TRL has recently re-visited its pioneering work (O'Reilly, 1993; Hopkin & Simpson, 1995) assessing the costs of road casualties and highlighted the need to update the approach to determining cost-effective countermeasures if we are going to prevent the wasteful impact of road collisions on society and economies.

According to road collision statistics published by the UK Department for Transport (DfT), the human costs and lost output make up over 2/3 of the total estimated cost of injuries on the road. We have reviewed these two cost components and suggest potential ways to improve upon the current methodology in this report.

The existing lost output estimation by O'Reilly (1993) and Hopkin & Simpson (1995) does not take into account progress of earnings through working life. As most casualties are young people, the 2% income growth rate significantly underestimates their future output potential. Currently, fatality is valued at net output and injury at gross output. This discrepancy should also be reviewed. Moreover, the burden of primary care and increase of road user journey times because of road collisions should be properly accounted for.

Regarding human costs, current data are based on Carthy et al. (1999), who attempted to address issues of behavioural biases including the impact of sequencing of questions used to assess people's willingness to pay for improved safety. TRL believes that we can go further. In the future, more sequences of questions can be run in parallel to cross-check values of risk reduction. Furthermore, route choice modelling can potentially close the gap between Willing-To-Pay (WTP) and Willing-To-Accept (WTA) values in Contingent Valuation (CV) questions. Econometric modelling techniques will also help explain relationships between WTP values and factors such as previous crash experience.

Our recommendations point to:

1. Enhancing the current cost-benefit analysis framework concerning road safety

2. Adopting a robust evidence base for appraising all casualty prevention interventions, including education, enforcement, and road and vehicle engineering safety measures

3. Harmonising methodologies across countries

The implementation of these recommendations will ensure that the economic costs and benefits of road safety measures can be compared on comparable terms across countries. In turn, a standardised appraisal of safety measures can lead to more informed and expeditious decision making for policymakers.

Contents

Glossary

Appraisal - the objective assessment of alternative policy options, including the baseline of no intervention and other possible interventions.

ASHE - Annual Survey of Hours and Earnings. A comprehensive source of information on the structure and distribution of earnings in the UK.

CBA - Cost Benefit Analysis. The systematic study to estimate, in monetary terms or otherwise, the strengths and weaknesses of options. In appraising public projects such as safety measures, CBA would involve parameters including discount rates, inflation forecasts and appraisal periods.

Chained approach - a pre-determined sequence of questioning to participants, often aimed at estimating the magnitude of cognitive bias in valuing health risks.

CV - Contingent Valuation. It is a survey-based economic research method for the valuation of non-market objects, such as the better quality of life associated from avoiding a road collision.

Discount rate - a rate used to calculate present values, recognising more weight should be given to cost and benefits in early years of appraisal than later years.

DfT - Department for Transport. The DfT is a ministerial government department responsible for the English transport network and a limited number of transport matters in other parts of the UK.

Endowment effect - a finding in economics that individuals are more likely to retain an object they own than to acquire the same object when they do not own it. This is explained through the higher value attached to objects currently in possession.

HCA - Human Capital Approach. A method of analysing the cost of road collisions, often adopted by developing countries, focusing on the gross output loss of road collision victims. It excludes the WTP elements that are part of the VPF calculations by some other countries.

Human cost - the part of the collision cost that concerns pain, grief and suffering to the casualty, relatives and friends, as well as intrinsic loss of life enjoyment in the case of fatalities.

iRAP - International Road Assessment Programme. The umbrella programme for Road Assessment Programmes (RAPs) worldwide which work to save lives and prevent serious road injuries.

Median earnings - the gross annual salary of an individual where half of the rest in the group earn more and half earn less.

MSG - Modified Standard Gamble. An assessment method built on Standard Gamble and includes sequencing and ranking of treatment options to refine values of an array of health states.

PSG - Pain, Suffering and Grief. The physical (including death) and mental impairment of the victim and their loved ones as a result of a road collision.

QALY - Quality-adjusted Life Year. A measure of disease burden, including both the quality and quantity of life lived. A year of life in perfect health is 1 QALY (1 year of life times 1 utility

value); a year of mediocre health (1 year of life times 0.5 utility value) and half a year of perfect health (0.5 years of life times 1 utility value) result in the same 0.5 QALY; death is 0 QALY.

RP - Revealed Preference. A quantitative econometric research method of analysing actual choices made. For instance, other attributes of two properties being the same, the one further away from the highway commands a premium that buyers actually pay. With enough data, the premium can be taken as the value of the other non-marketable attribute of tranquillity.

SG - Standard Gamble. An assessment method in quality of life research. Respondents are presented with a certain non-lethal symptom. They then have a choice of taking part in a hypothetical, experimental treatment that frees them from the symptom with a probability p, but with a probability 1-p, the hypothetical treatment fails and causes immediate death. This method enables the quantification of someone's preference for a specific health state, such as that caused by a road collision.

SP - Stated Preference. An economics research survey method. Respondents are asked directly how much they value a non-marketable object such as health attributes.

TTO - Time-Trade-Off. A technique in measuring the quality of life that someone is experiencing by asking how much time they are prepared to give up in exchange for what is left of perfect health.

VPF - Value of Prevented Fatality (VPF), sometimes also Value of Statistical Life (VSL). The total economic value of preventing a statistical fatality. The value comprises of the WTP value, medical costs and net output lost in the event of a fatal road collision.

VPI - Value of Prevented Injury. The total economic value of preventing a statistical injury. The value comprises of the WTP value, medical costs and net output lost in the event of a road collision which results in injuries.

VSL - See VPF.

WTA - Willingness To Accept. In the context of valuing non-marketable things such as health, the maximum monetary amount a person is prepared to take in exchange for tolerating a probabilistic or certain deterioration in life quality of themselves or others.

WTP - Willingness To Pay. In the context of valuing non-marketable things such as health, the maximum monetary amount a person is prepared to sacrifice to avoid or recover from a probabilistic or certain deterioration in life quality of themselves or others.

1. Introduction

Road collisions incur both significant human and economic costs. Understanding the scale of these costs is important: estimates are used by governments and highways managers when evaluating investments in road-safety measures. The current UK methodology divides the costs into two broad categories: the casualty costs that concern the victims, and the collision costs that relate to other aspects of the collision. The elements which make up this methodology are depicted in Figure 1.

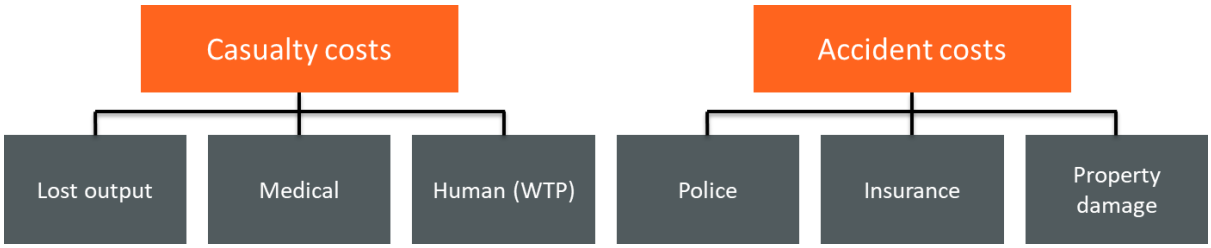


Figure 1: Road collision cost categories. Source: UK Department for Transport

Lost output relates to the economic value the killed or injured would have contributed to society had the collisions been averted. Medical costs[1] relate to ambulance and in- and out-patient services. The human costs are based on a Willingness-To-Pay (WTP) approach, where individuals express monetary values they are willing to pay to avoid injuries. Police and insurance costs relate to their respective administration costs, and property damage data are typically collected through insurance claims.

This current method estimates that had all reported collisions in 2019 in Great Britain been prevented, society would have saved £33 billion[2] or 1.5% of GDP according to data from the Department for Transport (DfT). According to road collision statistics released by the DfT, the human costs based on a Willingness-To-Pay (WTP) approach accounts for over 60% of the total costs. This is followed by property damage which accounts for 17%. The third most significant is the lost output resulting from collisions, making up 13%.

1.1 Lost output methodology unchanged since 1993

Nevertheless, the methodology for estimating lost output has not been revised since 1993. In a bottom-up approach, O'Reilly (1993) detailed appraisal treatments for fatal, serious and slight injuries. For fatalities in each age group, lost future earnings were derived from average income. These were matched with fatality statistics and net present values of lost earnings. For serious casualties, 62% of victims were found to recover in a year, 36% in 1-3 years, and 2% never to return to work in a Manchester area study (Hopkins & Simpson, 1995)[3]. Daily

[1] Detailed types of medical costs are outlined in Table 1 in Appendix A.

[2] https://www.gov.uk/government/statistical-data-sets/ras60-average-value-of-preventing-road-collisions

[3] See Table 3 of their paper for more detail.

income and working days lost were then applied to each age group using a 2% income growth rate and 6% discount rate. For slight injuries, 90% were assumed to recover in a year and 10% in 1-3 years. The income loss method was again applied. While the approach provided an intuitive guide to decision makers at the time, it does not account for:

1) **Progress through working life.** The current methodology takes the income of the deceased and assumes a 2% annual growth for their projected lifetime. However, median earnings for 40-49 years old are 3 times that for their 16-17-year-old counterparts. A 2% compounded growth significantly underestimates the step change professional experience adds to the economy in future years.
2) **The burden of care post collisions.** Medical costs are taken into account, but longer-term care needs have not, as far as we are aware. These are usually non-monetised but can be proxied by the number of hours of care needed. Where another member of the family takes the role, we should consider their forgone productivity (Aeron-Thomas et al., 2004).
3) **The build-up and diversion of traffic, as well as the cleaning of crash sites increases journey time.** This results in a reduction of productivity which has not been part of the DfT's road statistics.

These factors suggest road safety organisations and international bodies may be underestimating the economic costs of road collisions, particularly where the victims are relatively young.

1.2 Willingness To Pay (WTP) methodology unchanged since 1997

The methodology for estimating human costs has not been revised since 1997. This is despite advances made over the years on capturing individuals' attitudes towards the trade-off between risk and reward. The UK's WTP-based study undertaken by Jones-Lee et al. (1985) centred on the Stated Preference (SP)[4] approach. It was developed to value fatal injuries (Dalvi, 1988) and non-fatal injuries (Depart of Transport, 1994). The former is referred to as Value of Statistical Life (VSL) or Value of Preventing a Fatality (VPF), while the latter as Value of Preventing an Injury (VPI).

VSL has enjoyed popularity among government agencies in the field of transport planning. However, a major criticism of VSL is it varies based on the size of risk reduction. This means WTP – and effectiveness of safety measures – is not constant. As a result, a Contingent Valuation (CV)[5] / Standard Gamble (SG)[6] "Chained" Approach study by Carthy et al. (1999)

[4] Willing To Pay is typically measured through 1 of 2 ways. The first is Revealed Preference (RP) which applies hedonic pricing (pricing based on attributes) to examine trade-offs people make. An example is the higher wages required to attract workers in riskier jobs. The second is Stated Preference (SP) in which respondents are asked

[5] Contingent Valuation (CV) is a survey-based economic technique that asks respondents to trade off non-marketed goods. CV is often referred to as SP.

[6] Standard Gamble (SG) typically gives the respondents 2 choices: a certain less-than-ideal health condition versus a gamble between perfect health and death with known probability.

cross-examined trade-off between various states of wealth and health and concluded that WTP is sensitive to injury duration and severity. NERA (2011) reviewed these methods and recommended continuing the use of SP.

A comparison of international practices would help policymakers and transport planners understand the differences particularly between developed and developing countries. Sometimes such methodological contrasts are driven by gaps in data availability and as a result could warrant further improvement. More importantly, acknowledging the drivers behind the adverse economic impact brought about by road collisions is a key motivation in enhancing safety measures.

1.3 This report reflects on methodological progresses made

The use and design of transport systems should be economic decisions. For instance, a new motorway brings about employment and productivity but involves capital expenditure, maintenance, environmental impacts and expected casualties. For an existing road where considerable collisions have occurred, lowering the speed limit saves lives but delays trips. At one extreme, banning traffic entirely in Great Britain as a safety measure would have saved £33 billion in collisions (based on 2019 figures). Many countries have in fact imposed travel restrictions through legislation during the most infectious periods of COVID-19. The economic costs have been enormous, but social distancing measures and reduced travel will likely dramatically lower the final casualty figures as a result of the pandemic.

A robust framework for valuing the prevention of road crashes is key to rigorous Cost Benefit Analysis (CBA). This think piece therefore aims to:

1. Provide an up-to-date, high-level methodology for appraising economic lost output (Section 2). This will consider productivity increase through working lives, the burden of primary care and increase in journey time. As far as we are aware, this is the first time these important factors have been incorporated at the macro-level.
2. Compare approaches to valuing human costs internationally to reflect such diverse practices as Willingness To Pay (WTP), Willingness To accept (WTA), human capital approach (HCA) and iRAP Rule of Thumb (RoT) by countries (Section 3).

These analyses will provide better and more realistic ways to cost fatalities, injuries and crashes. This in turn allows governments and road authorities to conduct CBA more accurately and quickly. This will be conducive to the implementation of life-saving measures that avoid some of the economic burden caused by road collisions.

2. Revisiting lost output methodology

The existing methodology for valuing lost economic output relates to road injuries and deaths. Physical injury can prevent victims from carrying out the economic activity that they would have carried out. This represents an economic burden on society. Collision-related lost output is put in three categories: fatality, serious injury and slight injury. This corresponds with the road casualty statistics collected by the UK Department for Transport (DfT).

Within each category, O'Reilly (1993) assembled a model to estimate values, the components of which are summarised in the following sections.

2.1 Value of Prevented Fatality (VPF)

In valuing road collision deaths, the net present value of future earnings is estimated across age groups as summarised in Figure 2. The starting point is the average income belonging to the age group of the deceased[7]. This is adjusted by the statistical probability that the victim would have been alive at a future date had the collision not occurred[8]. The estimation also recognises that not all victims were economically active and adjusts earnings estimates by the participation rate[9].

2.1.1 *Discount rate*

The earnings estimate is then profiled into future years using 2 important factors. The first is an income growth rate of 2% per annum to reflect the growth of the UK economy. The second factor is the discount rate of 6% which reflects the Social Time Preference Rate (STPR). The discount rate converts the future earnings profile into a current or 'present' value of future income.

O'Reilly (1993) acknowledged different choices of discount rates can be justified, and reproduced the analysis using another discount rate of 5%. However, since the Green Book currently recommends that valuation of public projects discount at 3.5% per annum, it appears reasonable that VPFs are adjusted in accordance.

[7] Released in the Annual Survey of Hours and Earnings (ASHE).

[8] Published by the ONS in the National Life Tables.

[9] Published in the Labour Force Survey.

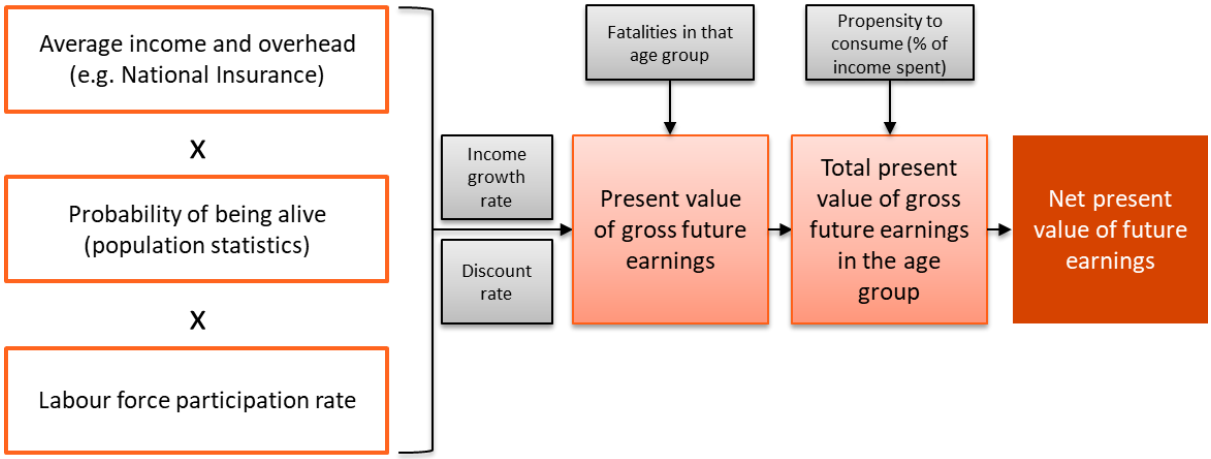


Figure 2: Current method for Value of Fatality (VPF) in each age group

2.1.2 *Income growth rate and progress through working life*

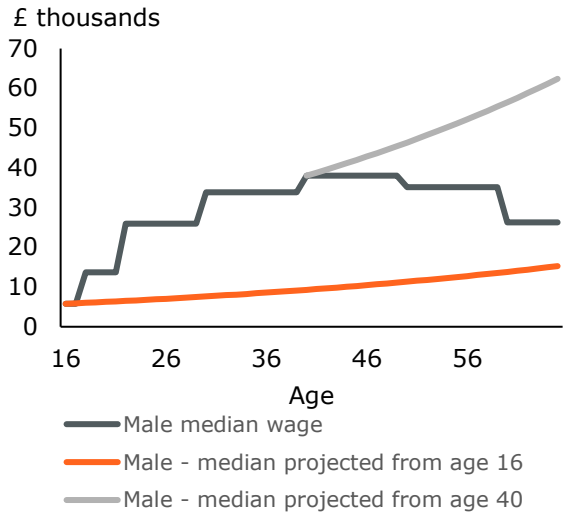
A major area for improvement in the 1993 methodology concerns the projection of victims' likely future income. Society invests in educating and training members of the community most heavily in their early years through to higher education. Although this funding becomes an economic sunk cost whichever income trajectory materialises afterwards, wage data reflect such additional value to the economy.

The 2% income growth rate therefore does not account for the step change in salary an average 16-year-old makes through working life. Likewise, the current parameter overestimates the future income of victims closer to retirement. Figure 3 below visualises the over- and under-estimation. The staircase-like median wage[10] lines are from the 2019 Annual Survey of Hours and Earnings (ASHE) by the UK Office for National Statistics (ONS).

For the average working man, the plateau comes at the 40-49 age group at £38,021 a year, 6.5 times that of 16 and 17-year-old males. This presents the above-mentioned estimation issues. Using the O'Reilly method of valuation (2% growth per year), a 16-year-old who died on the road would be expected to follow the bottom orange line in income. Given the increases in median income between 16 and 30 – 484% for men and 730% for women – this represents an underestimate of a young person's lifetime income. Indeed, following Figure 3, the 2% growth assumption would mean that subsequent age groups' median earnings are not met until the end of what would have been their expected working life. This observation is against the backdrop that over 90% of 16 years old are in education and work-based training (WBL) (Department for Education, 2019).

On the other hand, if the fatality happened at 40, the current method would calculate income as continuing to grow at the assumed 2% rate, achieving £62k and £38k for men and women respectively at 65.

[10] Includes incentive pay, e.g. commissions and bonuses.



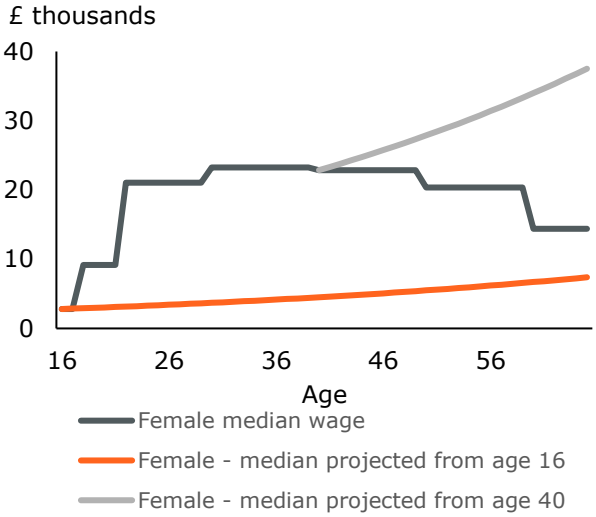


Figure 3a: Median annual salary for men **Figure 3b: Median annual salary for women**

Sources: Annual Survey of Hours and Earnings (ASHE) and TRL analysis

It should be recognised that individual future income is difficult to predict, and court cases often see extreme estimates based on assessment of earning potentials. Road collisions may also be unevenly distributed across income groups and this is an area of meaningful research going forward. However, neither of the above approaches seems to reflect the realistic income trajectories of victims at median salaries. What would appear reasonable in the first instance is to adjust income streams in accordance with the median wage curves rather than the uniform 2%. Median should prevail over mean in the analysis as the latter is likely distorted by a few very high earners.

2.1.3 *Propensity to consume*

In simple terms, the propensity to consume is the proportion of disposable income spent on private consumption. For instance, an individual who earns £10 and consumes £8 has a propensity to consume of 0.8. What is not spent on consumption is then saved by definition. The sum of propensity to consume and propensity to save is 1.

Since the DfT – then Department of Transport (DOT) – adopted the WTP approach for fatal casualties, lost output has been valued in net output. Net output is the income stream net of consumption. Following on from the example of a 0.8 propensity to consume, the net output for someone whose present value earning is £100 is then £100 x (1 – 0.8) = £20.

The rationale for subtracting consumption was potential double counting. DOT argued the WTP human costs already takes into account the joy of consumption that is lost in a fatality. It is problematic in that while VPFs take a net output approach, VPIs remain estimated based on gross output. Injury in many cases cannot be compared with fatality, but as far as the loss of joy in consumption is concerned, the same output approach should be adopted.

Moreover, the gross output should be preferred across estimations. The reason for this is that when a member of the community spends on consumption, it often becomes someone else's wage. For instance, an office worker buys lunch at a local grocery store which pays the cashier's wage. It might be regarded as joy on the purchaser's part, but it does count as productive activity recorded as part of GDP.

The lost output calculation assumes that any input forgone is not replaced. Dawson (1967) argued replacement of fatalities takes place by additional children or reduction in unemployment, but replacement can be slow, costly and inperfect. More work should be done on the displacement impact due to road collisions. Research into the types of fatalities and the degree to which replacement can take place will help decision makers understand the wider future impacts of road casualities.

The value currently used as the propensity to consume estimate (0.2) was suggested by O'Reilly (1993). As NERA (2011) has correctly highlighted, this is some way off the latest available data. Even in 1993, households' saving ratio – an estimate of propensity to save – was about 14% according to ONS's sector account data[11]. It has dropped to around 5% in 2019, meaning the propensity to consume is about 95%. This implies for every £100 of gross output, the net output only amounts to £100 x 5% = £5.

2.2 Value of Prevented Injury (VPI)

The sum of value in serious and slight injuries came at £8.6 billion in 2019[12] in mainland Britain or 70% of all injury accidents. The individual value is lower compared to fatality, but the number of injured far exceeds that of killed.

O'Reilly (1993) detailed the existing methodology for valuing serious and slight injuries. Figure 4 shows that serious injuries are considered in three groups: the majority (62%) in the first group recover in a year; some (36%) in the second group recover in 1-3 years; a few (2%) in the third never return to work. Figure 5 shows that slight injuries are similarly considered in two groups: the vast majority (90%) recover in a year; the rest (10%) in 1-3 years. The percentage splits of when the injured go back to work are shown in next to each category in these figures. The descriptors for the injuries were devised by Murray, Pitcher and Galasko (1994) and often referred to as Galasko's injury table. Accompanying percentages of each descriptor were detailed by Hopkins (1995) and adapted for clarity in Appendix A (Table 2).

[11] https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/dgd8/ukea

[12] 2019 prices, RAS60003: https://www.gov.uk/government/statistical-data-sets/ras60-average-value-of-preventing-road-collisions

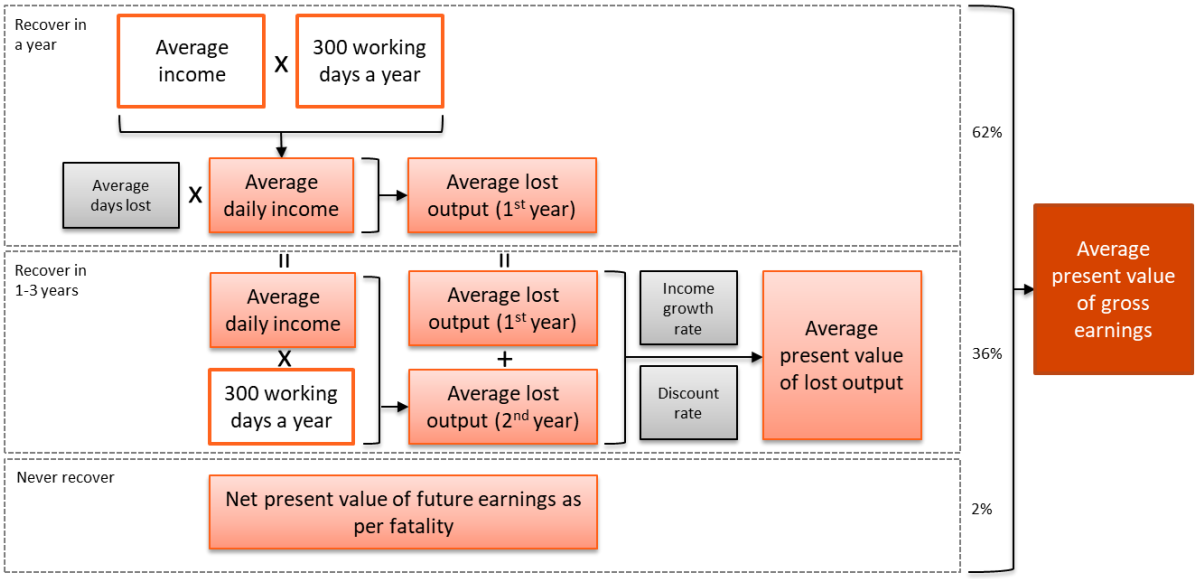


Figure 4: Current method for value of serious injuries in each age group

Source: O'Reilly (1993). Note: percentages are estimated in Murray, Pitcher and Galasko (1994)

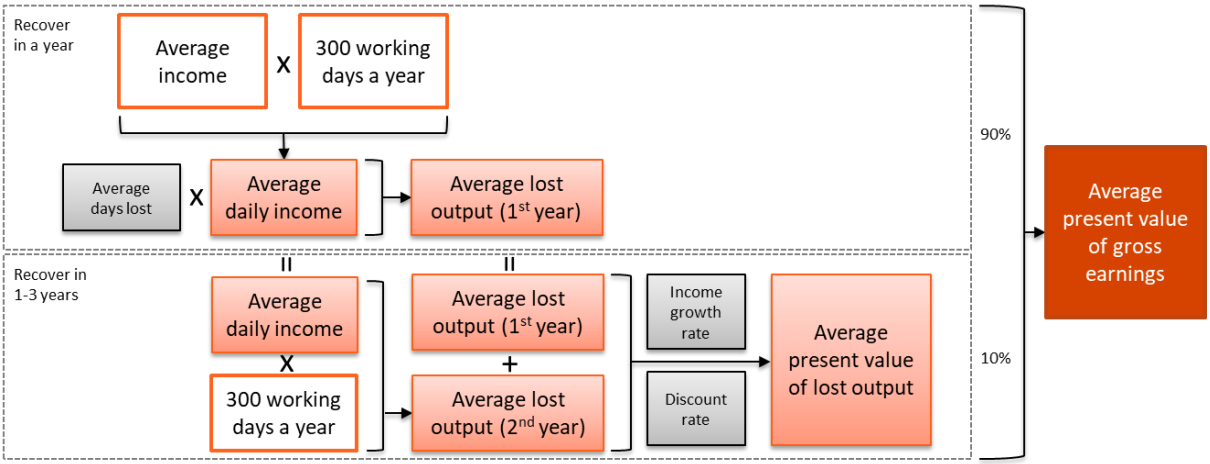


Figure 5: Current method for value of slight injuries in each age group

Source: O'Reilly (1993). Note: percentages are estimated in Murray, Pitcher and Galasko (1994)

Having an up-to-date and robust methodology for VPI just as important as that for VPF. Issues surrounding the discount rate and income growth discussed in sections 2.1.1 and 2.1.2 are also applicable. The number of working days lost for each type of injury were estimated in Tunbridge et al. (1990) and Murray et al. (1992). Existing methodology takes an average of these figures in deriving the average income lost, assuming 300 working days a year. This is discussed in more detail below.

2.2.1 *Working days lost*

The number of days lost is an important part of the model input for VPIs. There have been several plausible changes since the studies by Tunbridge et al. (1990) on which these numbers were based; these changes concerned the ways of working and recovery. Many more people are now able to work from home than in the 90s, and some injuries hinder work to a lesser extent than the commute itself. Means and speed of communication have also improved, meaning employers are better kept up to date with regards to the health state of their staff. These are expected to bring down the average days lost at work.

Nevertheless, a lot of road collisions result in regular out-patient treatments what have not been rigorously recorded. Tunbridge et al. (1990) was able to estimate that on average, fracture and whiplash injuries were associated with 72 working and 31 days lost respectively. As far as the author is aware, therapy visits post the first-phase main treatment have not featured in working days lost. Whether the employer bears the burden by ways of providing day leave for these visits – which by law they should – is irrelevant. The economic activity on the part of the out-patient is forgone and should be recorded as such.

2.2.2 *Recovery periods and casualty splits*

An in-depth study of road injuries in the Greater Manchester area by TRL commenced in 1987. It covered 1,344 car crash victims over 4 years. Researchers initially approached patients and at 6-month intervals for 48 months. The work produced in 2 interim reports by Tunbridge et al. (1990) and Murray et al. (1992) which examined the financial costs of treatment. A final report by Murray, Pitcher, & Galasko (1993) was later published to detail the long-term impact on time off work. However, the length of time that has since lapsed calls for at least a refresh covering more regions.

Hospital Episode Statistics (HES) published by the National Health Service (NHS) already provides admissions data. Length of hospital stay data are also provided by the OECD and Eurostat. However, neither of these series split data by road collision types nor track casualties' time off work. Part of any new data collection exercise should also enquire patients' way of working. This will help policymakers more comprehensively understand the economic cost of people seeking medical treatment of various types.

2.3 Burden of primary care on households

Finally, the existing output loss estimation methodology does not consider the economic burden of care outside the standard cost items (hospitals, care homes etc). There are also additional care responsibilities borne by the caregiver passed on to others within families and households as they become incapacitated or die. This also covers additional care support provided to the injured following road collisions. Caregiving within families and households is not measured in market value, but is no less significant to the economy. It takes away someone's time which can be otherwise productive. Transfer of care responsibility is also an additional burden to the care itself.

2.3.1 *Replacement carers following a fatality*

If a person tragically dies on the road, they may have caring responsibilities that need to be passed on after their death. If required, childcare would need to be rearranged, perhaps provided by surviving grandparents and relatives. Elderly care provided to some extent by adult children lost in a collision also needs to be replaced. Persons of any age (including children) may have caring responsibilities from family members with additional needs. Even in cases of the vast majority of young people who have no present caring responsibilities, future needs (for example, for parents who are not currently elderly) may also become a burden to relatives or wider society. These new care responsibilities create a secondary lost output, if it means the replacement caregiver must give up part of their working time to fulfil care duties. Considering the additional impact of replacement childcare, this is expected to be significant. In 2018, 741[13] road deaths were registered in age range 25-54 in Great Britain. Casualties in this age category are most likely to have young children for whom surviving or foster parents would have to give up working time.

2.3.2 *Replacement carers and new care needs following an injury*

Those injured on the road might require someone to look after their children in a way similar to those killed, but they might also need someone to look after themselves. Even though medical costs have been well documented (see Table 1 in Appendix A), the burden of caregiving has not. In many cases, their loved ones may be taking time off to provide care, which also represents lost output to the economy.

To estimate this burden of care, a new survey or an addition to a previous survey structure is required. This would include reviewing the Galasko injury descriptors within Murray, Pitcher and Galasko (1994). Patients can be asked to estimate the length and intensity of care their households would have to provide when they get discharged. The time required can then form the basis for cost of care modelling. As 160,597[14] road casualties in 2018 in Great Britain suffered various degrees of severities, the burden of care will be a significant part of VPI.

2.4 Increase in journey times following road collisions

Delays after a road crash are common. This increase in journey time is a result of reduced road capacity, other drivers slowing close to the incident and/or emergency services/recovery vehicles having to attend the scene. These may cause the site to be closed for some time. If site cleaning and investigations are involved, there would be further delays to journey times. Smart motorways and more traditionally the radio can report useful road information to drivers to divert traffic. Smart devices provide further estimates to best routes and updated journey time in real time.

[13] RAS30035 Deaths by age and gender: https://www.gov.uk/government/statistical-data-sets/ras30-reported-casualties-in-road-collisions

[14] RAS30034 Reported casualties by severity: https://www.gov.uk/government/statistical-data-sets/ras30-reported-casualties-in-road-collisions

Nevertheless, information on traffic diversion, build-up has not been captured in many countries. GB data account for property damage but the increase in journey time is currently not estimated. As such, the resulting cost of increased journey time it also not featured in the lost output calculation. It seems clear that delays represent an economic burden and should be costed appropriately.

MotorGraph, for instance, provides timely and relevant information about the UK's strategic road network. Relevant information can also provide a realistic picture of how traffic has built up or diverted elsewhere. Some of these data have already been deployed to control traffic light signals for instance. Combined with the increased journey time cost, journey purpose splits and distribution of passengers across affect vehicles, collision-related delay can be modelled efficiently.

3. Reviewing the WTP approach

In the UK, the human costs of road collisions are the most important part of fatality and injury values. These costs account for the pain, grief and suffering (PGS) that follow collisions. The non-marketable nature of these negative attributes associated with road collisions presents great difficulty concerning reasonable estimation. In order to value these health-related outcomes following road crashes, the application of Willingness To Pay (WTP) and Willingness To Accept (WTA) approaches to the valuation of these costs have been extensively researched and developed since the 1980s and applied to an array of non-marketed features. See Figure 6 below for an illustration of how these methods are currently used to obtain outputs.

Many developing countries opt for the Human Capital Approach (HCA) rather than the WTP approach. The HCA evaluates the gross economic output forgone as the road user dies or becomes injured in a road collision. The WTP approach, on the other hand, asks people how much they are willing to pay to avoid injury, measured in risk. WTP values are generally higher than HCA values. This observation can be a result of more developed countries adopting WTP and developing countries adopting HCA. Wignen and Stipdonk (2016) argued that the two approaches should be complimentary, whereas iRAP (2016) recommended WTP values be adopted where resources allow.

3.1 Overview of WTP/WTA

In economic theory, the WTP and WTA are methods of valuing goods and services when there is no market value. There is no obvious market valuation for good health, or for suffering so a WTP or WTA approach is appropriate. In this case, WTP asks participants how much money they are willing to forgo to achieve a prescribed health condition increase. Likewise, WTA asks how much money participants would need to receive to offset a move to a worse health state.

3.1.1 *Stated Preference and Revealed Preference*

There are two approaches to the measurement of WTP and WTA: Stated Preference (SP) and Revealed Preference (RP). RP evaluates these values as “revealed” by money spent on something that is marketable. For instance, two otherwise identical properties on the market are priced differently because one is near railway tracks and the other a quiet park. The price gap could therefore be attributed to the noise and air quality differences between the property locations. Often, that would not be the only difference and the technique in seeking out the value of different non-marketable elements is called Hedonic Pricing or Hedonic Regression. It can help policymakers put value on measures of life satisfaction such as the Life Quality Index (LQI).

SP on the other hand asks people the amount of money they are willing to pay or accept in exchange for a non-marketable feature. The method to extract value estimates is often referred to as Contingent Valuation (CV). When first devised, questions aimed at direct elicitation. For instance, participants in studies were asked such questions as ‘how much would you accept in exchange for a higher risk of death?’. CV is often applied in conjunction with the Standard Gamble (SG) method – a method of ascertaining the risk people are willing to take in order to obtain full health.

CV methods including SG are the most common approach to WTP/WTA studies for road collision risk. These are explained further in the next paragraph.

3.1.2 *Contingent Valuation and Standard Gamble approaches*

SG studies present a participant with a hypothetical baseline health condition, which the participant must imagine is their current health state. They then face a choice of treatment. If they reject the treatment, their health state remains at the hypothetical baseline. If they accept the treatment however, one of two outcomes will materialise. Either the treatment is successful and full health is restored, or else the treatment fails and leads to certain death. The probabilities of each respective outcome are made known to participants and the participants are invited to choose whether to accept or reject the treatment.

The SG method has drawn criticism that participants are often reluctant to accept the treatment because people are generally loss averse, and so remain in the poor health state rather than risking death. This loss aversion was first revealed by Tversky and Kahneman (1979) who found that people have to be compensated for more than the amount lost. The Modified Standard Gamble (MSG) approach is now often used in place of the SG, as this Gamble replaces the hypothetical death with another non-death injury state, allowing participants to make evaluations that better reflect everyday choices.

Over the years, SG and MSG studies have contributed to measures of life value. The one the UK adopts for valuing road collision prevention is the Value of Statistical Life. In other public policy areas such as health intervention, Quality of a Life Year (QALY) and Time Trade Off (TTO) are also popular.

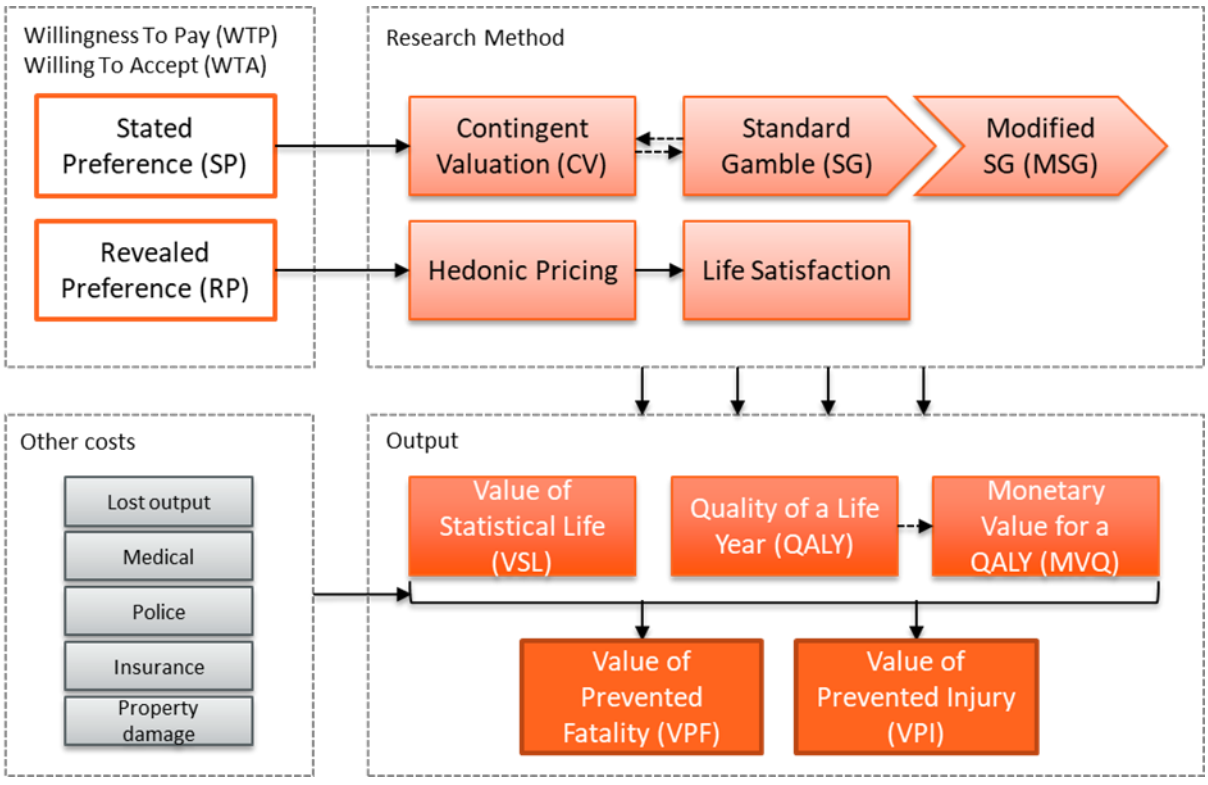


Figure 6: Value of life estimation mechanisms

3.2 Concerns with methods prior to 1997

Human costs are not only the most significant element of road traffic collision cost in the UK but also the most contentious because of the subjectivity of the approaches to deriving figures. Competing approaches and methods have been employed in different countries. Many developing countries do not assess human costs due to the lack of available resources or demand for carrying out such studies. Table 3 in Appendix A shows countries which adopt WTP within a selected group and accompanying latest estimates.

Well-informed road safety policy decisions rely on a robust knowledge and evidence base as to the value of casualties prevented. This is especially true when the various proposed safety measures on roads with different existing safety standards must be prioritised. The absence of an international baseline in understanding the human costs of transport collisions was highlighted in and prompted the Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO, 2006). Several European countries have since followed the guidelines therein and published their own WTP figures.

A voluminous literature in psychology and behavioural economics has sprung since the dawn of WTP/WTA. Beattie et al. (1998) and Carthy et al. (1999) discussed in depth several crucial factors that influence these resulting values. Taking the wider literature into consideration, these factors are:

1. Embedding - much discussed in behavioural economics, the embedding effect refers to the respondents' unfamiliarity towards the non-marketed goods. Beattie et al. (1998) bundled different risk reductions of death and injuries. For instance, the bundle consists of a reduction of 3 in 100,000 in risk of death and 10 in 100,000 in risk of a certain type of injury. Within a group, some respondents expressed same positive contingent values (CVs) for the bundle as well as individual reductions. This implies that by bundling the risk reductions differently, a wide range of estimates could often result.
2. Scope - in standard economic theory, the law of diminishing marginal rate of substitution dictates that people are willing to pay more for the first unit of a good. Having consumed the first unit, their rate of substitution – willingness to exchange for a second unit – decreases. In the context of risk reduction, 3 in 100,000 reduction in the risk of fatality (F3) should not be worth 3 times 1 in 100,000 reduction (F1). This is because people are supposedly willing to pay less for the extra units of safety. Nevertheless, F3 should be worth strictly greater than F1 since more safety is desired to less, keeping all else constant. However, 42% of participants in the 1998 study were found to have valued F3 and F1 the same in the first stage. This highlights the susceptibility of rationality assumptions in any WTP study.
3. Sequencing - Beattie et al. (1998) devised a series of five direct CV questions and put them two orders, bottom-up and top-down. The same questions were asked only reverse order to each other. It found statistically significant differences in corresponding values that in turn influenced the VSL. For a risk reduction of death of 3 in 100,000 for instance, the top-down approach concluded 48% higher in median VSL than the bottom-up approach. The difference in mean values is even higher, though such observations were commonplace across WTP/WTA studies.

4. Framing - If respondents valued X and then X+Y (where X and Y are risk reductions), Y can be inferred as the difference between the two values. However, this way of backing out incremental values of additional 'safety' was at odds with when participants were asked directly to value Y. In fact, if Y were the risk reduction of 1 death in 100,000, the incremental approach more likely elicits lower VSL than the direct approach. It is therefore of great importance that any methodology highlights the approach used and tries to replicate results using several chains of questions.
5. Endowment - The endowment effect refers to the higher value placed on goods one is already in possession of. Kahneman et al. (1991) robustly demonstrated this endowment effect, or status quo bias, is significant in economic decisions. This is highly relevant in the WTP/WTA approach. In WTP studies, participants were asked how much they were willing to pay for some enhanced level of safety. In WTA studies however, subjects were asked how much they were prepared to be compensated for less safety. Subjects felt they were first entitled to safety and then were to have it taken. They would then demand a lot more than if they were not entitled to and must pay for safety.

3.3 International experience of WTP

The early pioneering work of Schelling (1968) and Jones-Lee (1976) opened a door to the Willingness To Pay paradigm. An increasing number of developed countries have since shifted from the Human Captial Approach to one of the Willingness To Pay Approaches. This section looks at how Australia, France and Singapore have carried out an evaluation of their life values from which the UK may draw some lessons.

Unlike many economic measures, international benchmarks on the value of road collision prevention are few and far between. Even for countries like the UK that do publish WTP figures, data have not been updated at regular intervals. This section looks at some international experience which represent good practice in social research and economic modelling.

3.3.1 *Australia shifted to interim WTP values*

Australia started a transition process to WTP with an interim study of Willingness To Pay values of road collision prevention (Roads and Traffic Authority, 2008). This was a shift from the traditional Human Capital Approach that put the value of a life at £1 million (ASD 1.8 million) in 2010 prices to WTP value of £3.85 million (ASD 6.96 million) in 2010 prices. In the Austroads (2015) report, researchers recognised the need for targeted pilots before rolling out a national exercise. The resonates with one of the recommendations by NERA (2011) surrounding consistency.

Similar to the UK approach, interviews aiming to elicit SP from patients were conducted. However, the sample size was limited to 210 drawn from Sydney and Bathurst in the interim study. Going forward, Austroads (2015) recommended getting a broader sample that covers a wider range of injury types, road types, deomgraphics and road users. This recommendation seems widely applicable and any future exercise in the UK should maintain a diverse pool of respondents.

3.3.2 *French study made use of logit and tobit models*

Haddak (2016) conducted an WTP study using Stated Preference in the French region of Rhone. The study interviewed over the phone 2,216 residents to choose among road projects with different levels of safety. Participants were asked to indicate how much they were willing to pay for reduced risk on the roads. It is worth noting that instead of trying to find a balanced sample in terms of demographics, the paper controlled for variables concerning the repsondents. These are summarised in a logit model similar to:

$$WTP = \beta_0 + \beta_1 Lyon + \beta_2 Age + \beta_3 Male + \beta_4 Sequela + \beta_5 Income + \beta_6 Accident$$

Lyon is a dummy variable for those who lived in the Greater Lyon area. Age corresponds to the group that the respondent's age lied within. Male is a dummy variable for male residents. Sequela is safety level attached to the project: A to reduce minor injuries, B to reduce slight injuries, C to reduce serious injuries and D to reduce fatalities. Income refers to the respondents' income and collision is a dummy variable for if they or their relative had a collision in the last year.

The logit model allowed for variations in demographics and other relevant factors in the assessment of value of safety measures. Moreover, the tobit model was allowed to censor those participants who refused to engage with the exercise. A further technical paper established a statistically relationship between income and the subjects' willingness to pay (Haddak et al., 2016).

3.3.3 *Singapore surveyed route choices with different safety levels*

Le et al. (2011) documented how Singapore moved from HCA to WTP. Their study adopted the popular CV approach, but instead of asking CV questions directly, participants were asked to choose between routes A and B. Route A takes 20 minutes, is faster than route B by 8 minutes, but recorded 3 instead of 2 fatalities last year. This took away the endowment effect of starting at a particular level of safety.

In doing so, Le et al. (2011) found that WTP:HCA ratio was 1.68. This reflects the higher monetary value that subjects are willing to give up for avoiding collisions than the economic output itself. Further work would need to be carried to establish the data anlaysis process in the Singaporean study, but at first glance, this ratio is lower than the WTP:HCA ratio of Australia which is 3.87 (Austroads, 2015). Part of the reason for that could be the WTP approach in eliciting responses. While direct CV questions on 'how much you would pay to lower your risk' creates endowment, route choices dodge that status quo bias.

3.4 Scope for further work in WTP

The principal studies by Beattie et al. (1998) and Carthy et al. (1999) that underlie the current WTP approach used in the UK were well thought through in terms of behavioural design. They repeated exercises in permutations to satisfy themselves that results were not affected by behavioural bias. Where they could not, they clearly highlighted their concerns. One such example was the necessity to omit 16 cases in the MSG exercise as it gave rise to infinite

marginal rates of substitution for safety. The then UK Department of the Environment, Transport and the Regions (DETR) consciously continued its WTP values off the back of the work.

However, given the further progress made in design and estimation methods, it is reasonable to suggest that more can be done, and the available literature supports that view. The following paragraphs describe five alterations to the current methodology which could be considered.

3.4.1 *Estimate both WTP and WTA and recognise they are inherently distant*

There is ample literature including Beattie et al. (1998) and Carthy et al. (1999) that establish the endowment effect which drives the disparity WTP and WTA values. People, on average, value what they already possess more than something they do not yet own. WTA values are therefore typically larger than WTP values; people demand more in compensation for a poorer health outcome than they are willing to pay for an improved health outcome. It seems therefore a futile exercise to find ways to match these estimates. Nevertheless, future work should look to produce parallel WTP and WTA estimates to sanity check WTP results. On average, WTP:WTA seems to centre around 1:4, although the range can be significant (Austroads, 2015).

More importantly, it remains unclear why WTP should prevail over WTA. WTP treats road collisions as a probabilistic by-product that road users consent to taking to the road. Road safety is hence a privilege to be paid for. On the other hand, WTA treats road safety as a given, and that any crash is an infringement on the victims' right to wellbeing. There are grounds for either view, just as healthcare can be a privilege to pay for (e.g. the US) or a given (e.g. the UK, at the point of use). However, the decision to use WTP over WTA should be explained and justified, rather than taken for granted.

3.4.2 *Choice modelling to resemble route and infrastructure choices*

There are possible solutions to bridge the gap between WTP and WTA values. This can be achieved by removing the 'endowment' element of the questions. One group of such studies – e.g. Haddak (2016) – asked participants to choose between infrastructure proposal that come with different levels of risk. They remove the attachment of 'how much will you pay to lower your risk'. At least prima facie, respondents in such experiments do not have an entrenched starting point to then have to buy or sell their safety. Another type of study – e.g. Le et al. (2011) – focuses on route choices as described in Section 3.3.3.

3.4.3 *Econometric models are needed to account for socio-economic variables*

Previous studies undertaken have attempted to obtain socio-economically representative samples. Nevertheless, since 1997 considerable progress in econometric modelling techniques has been made in relation to controlling for these variables. Such models often increase the power of statistical tests by being able to accommodate larger and varied samples. Haddak's (2016) example is a step forward since Beattie et al. (1998), who tried to collect a 'representative' sample based on household income and other demographic variables. However, it is hard to imagine that income is not related to Willingness To Pay (for

anything). The same argument can be made of experience of road injuries. It is important to be able to set a baseline that controls for these variables.

3.4.4 *Survey design with up-to-date technology to scale up responses*

Survey design was found to significantly influence WTP and WTA outcomes. Any new data collection should therefore have regard to the behavioural biases discussed in Section 3.3. New studies using CV/SG questions would therefore require multiple sequencings of bundles. These results should also be compared with the route choice approach that builds on Le et al. (2011). An undertaking of this nature will be costly if all conducted via face-to-face interviews. Consideration should therefore be given to the use of internet-based surveys following a face-to-face pilot.

3.4.5 *Valuation of others' pain and suffering*

Furthermore, the detailed considerations in Section 2 still has not resolved a related issue to the WTP approach. It mostly concerns the willingness of the person involved in the scenario to pay to lower *their* personal risk[15]. They might well place higher valuations for risk reduction to their loved ones, but this area has been under-researched. This seemingly altruistic preferences can be perfectly rational, since in most cases someone's pain will be someone else's grief. If the WTP approach is justified, then an interpersonal WTP approach has a role to play.

[15] The Valuation of Environmentally Related Health Impacts (VERHI) study in 2006-2009 included relevant valuation of safety concerning respondents' children.

4. Concluding remarks

In the UK, lost output was first modelled by O'Reilly (1993) and later on Hopkin and Simpson (1995). However, subsequent studies have discovered scope for improvement to achieve consistency in estimating injury costs. These experiments highlight the behavioural biases that are inherent in the human appreciation of road safety.

Meanwhile, econometric techniques have made progress in social science research. Models can establish statistical relationships between variables including past collisions and willingness to pay for safety. As road safety improves, more members of society will have never experienced a road crash. While this represents real progress, policymakers require that evidence base to understand the value of money for public safety measures.

Moreover, technology like MotorGraph and online surveys have made it possible to collect traffic and SP data on a larger scale for much less expense. The increase efficiency of data collection using these tools can lead to faster set up of pilot studies and modelling work, and potentially greater insights.

This section summarises the finding of this study and lists recommendations going forward.

4.1 Summary and recommendations

There is a trend of developed countries shifting from HCA to WTP. In the UK, the existing methodology would benefit from an update from that employed in 1993. This report has examined the human costs (WTP) and lost output, respectively the first and third most significant component in the total value of collision prevention. It is not to say other elements are not important. Property damage estimation relies on the mark-up of unreported cases; robust assessments of unreported cases could be made by deploying road network monitoring.

4.1.1 *Lost output should build on the existing framework*

Progress through working life has been largely ignored by the 2% income growth rate. This should be modelled based on a more realistic income trajectory obtained from the ASHE data. A decision should also be made to align the output estimation for fatality and injury. It seems odd to calculate the net output for the former, but gross for the latter. The number of working days lost and casualty splits, even if unchanged to this day, would benefit from confirmation since Murray et al. (1993).

In addition, the increase in journey time has been realistically modelled elsewhere, but not as part of the DfT's statistics. Site clean-up and traffic diversion are costly and should be part of the lost output figures.

4.1.2 *New approaches have emerged to understand WTP's room for improvement*

Behavioural biases are found to have influenced WTP and WTA values. Route choices appear to have bridged the gap somewhat, but more explicit work is needed to uphold that view. Econometric techniques developed since Carthy et al. (1999) can also better inform future funding of road safety measures. The advent of online surveys also provides a means for

scaling up responses in a cost-effective way. All these developments point to the need to refresh the last CV/SG exercise in 1997, and to think about the feasibiltiy of regularly updates in the future. This special consideration recognises WTP accounts for just under two thirds of total costs of injuries on the roads.

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Appendix A Tables

Table 1: medical cost categories for serious and slight injuries

In-patient days	Intensive care unit
	Neurosurgery unit
	Plastic surgery unit
	Ward
Outpatient visits	A & E department
	Orthopaedic clinic
	Fracture clinic
	Physiotherapy clinic
	Other clinic
Other services	Emergency ambulance journeys
	Other ambulance journeys
	District nurse hours
	Appliances

Table 2: Lengths of recovery in serious injuries (Hopkins, 1995)

Injury code and duration in hospital	Recovery in	% of casualties
F: no overnight	Within a year (3-4 months)	19%
W: 2-7 days	Within a year (3-4 months)	13%
V: no overnight stay	Within a year (mild permanent)	5%
S: 1-4 weeks	Within a year (mild permanent)	12%
X: 1-4 weeks	1-3 years	36%
N (limbs): weeks, possibly months	Never return to work (paraplegia/quadriplegia)	2%
L (head): weeks, possibly months	Never return to work (severe head injuries)	

Table 3: Human costs valuation approaches by selected countries

HEATCO table IX.5

Willingness To Pay	**Human Capital Approach**
United Kingdom	Canada
United States	France
Sweden	Germany
New Zealand	Poland
Australia (piloted, pending a national study)	Latvia
Austria	Lithuania

Sources: HEATCO (2006) Table IX.5, Austroads (2015) and iRAP (2016) Tables 1 and 2.

Improving our Understanding of the Cost of Injuries on the Road

Road collisions cause immense human suffering and economic loss. The robust assessment of relevant costs is important in supporting Cost Benefit Analysis (CBA) of safety measures. In the UK, the methodology for evaluating these costs has been in use since 1990s. TRL has recently re-visited its pioneering work (O'Reilly, 1993; Hopkin & Simpson, 1995) assessing the costs of road casualties and highlighted the need to update the approach to determining cost-effective countermeasures if we are going to prevent the wasteful impact of road collisions on society and economies.

The resulting recommendations of this review point to the need of:

1. Enhancing the current cost-benefit analysis framework concerning road safety

2. Adopting a robust evidence base for appraising all casualty prevention interventions, including education, enforcement, and road and vehicle engineering safety measures

3. Harmonising methodologies across countries

The implementation of these recommendations will ensure that the economic costs and benefits of road safety measures can be compared on comparable terms across countries. In turn, a standardised appraisal of safety measures can lead to more informed and expeditious decision making for policymakers.

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